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Relative Merits of Four Methods of HARVESTING and PRESERVING ALFALFA FORAGE for DAIRY FEED

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UNITED STATES DEPARTMENT OF AGRICULTURE
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SILAGE and barn-dried hay contain more nutrients than field-cured hay.

Barn drying a hay crop with forced air is a valuable supplement to field curing or silage making.

Milk produced by cows fed alfalfa silage has a higher nutritive value than milk produced by cows fed field-cured hay.

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Relative Merits of Four Methods of HARVESTING and PRESERVING ALFALFA FORAGE for DAIRY FEED . . . . . .

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In most areas of the United States, large yields of good quality harvested forages are necessary for the adequate and economical winter feeding of dairy cattle and other livestock.

Some nutrient losses occur during the harvesting and storage of field-cured hay under the most ideal conditions. Harvesting losses are increased by rain, cloudy weather, and other unfavorable conditions.

Many farmers are trying to reduce harvesting losses and increase the yield of preserved forage by harvesting part of their hay crop as grass silage or as forced-air barn-dried hay. Some farmers are making dehydrated hay. Considerable information is available regarding each of these methods of hay harvesting; but very little information is available as to their relative value under comparable conditions.

To provide information regarding the relative merits of harvesting and preserving forage by different methods under comparable conditions, experiments were carefully and painstakingly conducted at the Agricultural Research Center, Beltsville, Md., with 6 cuttings of alfalfa over a 5-year period. The experiments were conducted jointly by dairy husbandry, agricultural engineering, and forage crops research specialists and hay grading specialists of the United States Department of Agriculture. The methods used and results obtained are reported in detail in Technical Bulletin 1079.[1]

THE BELTSVILLE EXPERIMENTS

The Beltsville experiments were conducted to determine the relative merits of harvesting forage as field-cured hay, barn-dried hay, wilted silage, and dehydrated hay, by comparing: (1) The labor and equipment-hours required for harvesting and storing the crop by each method, (2) the length of time the crop is exposed to the weather after it is cut, (3) the losses of dry matter and feed nutrients during harvesting and storage, (4) the yield, composition, and quality of the forages produced, (5) the value of the forages for milk production and for animal growth, and (6) the effect of the forages, when fed to dairy cows, on the vitamin A potency and quality of the milk and butterfat produced. Table 1 shows the botanical composition of the forage harvested.

[1] SHEPHERD, J. B., et al. EXPERIMENTS IN HARVESTING AND PRESERVING ALFALFA FOR DAIRY CATTLE FEED. U. S. Dept. Agr. Tech. Bul. 1079, 147 pp., illus. 1954.

TABLE 1.—*Botanical composition of the forage crop used in the 6 experimental harvests, 1945–49* [1]

Harvest	Year	Cutting	Botanical composition of crop				Stage of bloom of alfalfa	Leafiness of alfalfa
			Alfalfa	Ladino clover	Grass	Foreign material		
			Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	1945	1st	76	14	1	9	5–10	52
2	1945	2d	79	15	3	3	10–25	54
3	1946	1st	70	7	5	18	50–75	47
4	1947	2d	92		2	8	20–30	46
5	1948	2d	80		15	4	50–100	48
6	1949	2d	97		(2)	3	20–30	39

[1] Average for all fields and harvesting methods.
[2] Trace.

At each harvest, the forage to be harvested was divided into several fields. Each field was then subdivided into several long, narrow plots of 1 to 2 acres, one for each method of harvesting. This plan assured closely similar forage for all the methods of harvesting being compared. The forage for the different harvesting methods was all cut and harvested simultaneously.

The forages that were compared in each harvest were as follows:

Harvest 1—Field-cured hay, barn-dried hay (dried with supplemental heat), and wilted silage.

Harvest 2—Field-cured hay, barn-dried hay (no supplemental heat), and wilted silage.

Harvest 3—Field-cured hay, barn-dried hay (no supplemental heat), and wilted silage.

Harvest 4—Field-cured hay, barn-dried hay (with supplemental heat), wilted silage, and dehydrated hay.

Harvest 5—Barn-dried hay (with supplemental heat), wilted silage, and dehydrated hay.

Harvest 6—Barn-dried hay (with supplemental heat), barn-dried hay (no supplemental heat), and wilted silage.

Double reversal, 3-way, 120-day feeding trials were conducted with the forages from all harvests except the first, to determine their value for milk production and their effect on the vitamin A potency of the milk. Continuous feeding trials were conducted with the wilted silage from harvests 1, 3, and 4 to determine its effect, as compared with purchased alfalfa hay, on the vitamin A potency of winter milk. The effect of the forages on the quality of milk and cheese, the value of the forages for growing dairy calves, and the antirachitic effect of the forages were studied with the forages from harvest 2.

WEATHER CONDITIONS

Weather conditions during the field harvesting and barn drying are shown in table 2. About 50 percent of the hay was rained on (1, 2, or 3 showers). About 25 percent was damaged considerably by rain.

TABLE 2.—*Weather conditions during the field-curing periods and the barn-drying periods of the 6 experimental harvests*

Harvest	During field-curing periods						During barn-drying periods	
	Temperature	Humidity	Sky	Rainfall		Drying conditions	Rainfall	Drying conditions
				Days [1]	*Inches*		*Days* [1]	
1	Warm to moderate	Moderate to high	Clear and partly cloudy.	1	0. 06	Average	1	Fair.
2	Warm to very hot	do	do	0	0	Good	0	Do.
3	Very cool	Low	do	1	. 22	Poor	3	Poor.
4	Warm	Moderate	do	5	1. 06	do	3	Do.
5	do	High	Partly cloudy and cloudy.	4	1. 17	Very poor	5	Very poor.
6	Very hot to cool	Moderate to high	Clear to cloudy	2	. 19	Average	5	Do.

[1] Includes days with 0.01 inch or more of rainfall.

About 20 percent of the barn-dried hay was wet by 1 or 2 showers, and 12 percent of the wilted silage and 8 percent of the dehydrated hay was wet by 1 shower.

STORAGE CONDITIONS

Field-cured hay was stored in the mow in a natural, long condition, mostly with 19 to 22 percent of moisture but in 1 case with 32 percent of moisture.

Forage for barn-dried hay was stored on the hay drier either long or chopped with a long cut (3 to 4 inches theoretical). The forage contained 34 to 52 percent of moisture as stored and was dried to 10 to 14 percent of moisture. The barn drier consisted of a side plenum chamber and either tapered ducts or a slatted floor. Forced air was supplied at the rate of 15 cubic feet per square foot of floor area. Sufficient supplemental heat was used to provide a temperature rise of 15° to 20° F. One lot was dried using 6 to 8 cubic feet of air per minute per square foot of floor area and a supplemental temperature rise of 40°. Barn drying required from 7 to 19 days without heat and 4 to 11 days when supplemental heat was used.

Forage for wilted silage was chopped (¼- to ⅜-inch cutter setting) and stored with 61 to 64 percent of moisture in a 10- by 25-foot conventional tower silo. No additives were used. From 3 to 5 feet of heavy unwilted crop was blown in on top. The top was leveled off and tramped once a day for 3 days after filling, and tramped next to the wall twice a week for 3 weeks while settling. The silage had a mild, pleasant odor and a pH of 4.15 to 4.56.

Forage for dehydrated hay was field chopped (¼- to ⅜-inch cutter setting), brought to the dehydrator with 54 to 74 percent of moisture, dehydrated in a half hour or less to a moisture content of 6 to 9 percent, and then sacked. A portable, 2-pass, rotary, pneumatic dehydrator was used. It had a dry-hay capacity of 700 to 1,000 pounds per hour, with inlet temperatures usually ranging from 700° to 900° F. and outlet temperatures ranging from 225° to 300°.

LABOR AND EQUIPMENT REQUIREMENTS

All forage from the first three harvests and the rain-damaged field-cured hay from the fourth harvest was loaded onto trucks in a natural, long condition with a heavy-duty hay loader. Forage from the last three harvests was field chopped from the windrow and blown onto trucks or trailers.

When a hay loader was used (table 3), labor requirements per ton of dry matter preserved for feeding were slightly higher for wilted silage than for barn-dried hay, and slightly higher for barn-dried hay than for field-cured hay made in good weather. Considering all operations, total equipment-hours were the same for wilted silage, barn-dried hay and field-cured hay.

Rain during curing reduced the yield of field-cured hay, and it was necessary to turn the windrows after each shower. This materially increased both labor and equipment-hours for rain-damaged field-cured hay.

TABLE 3.—*Labor and equipment-hours required when forage was harvested with a heavy duty hay loader* [1] [2]

Labor and equipment items	Field-cured hay	Rain-damaged field-cured hay	Barn-dried hay [3]	Wilted silage
	Hours	*Hours*	*Hours*	*Hours*
Labor	4. 33	6. 30	4. 59	4. 87
Tractor	1. 57	3. 38	1. 32	1. 35
Mower	. 53	. 65	. 47	. 47
Rake	. 84	2. 46	. 44	. 35
Loader	. 44	. 66	. 41	. 48
Truck	1. 99	1. 84	1. 30	1. 66
Silo filler				. 54
Hay hoist	. 30	. 28	. 41	

[1] Per ton of dry matter preserved for feeding.

[2] Includes harvests 1 and 2 in 1945, harvest 3 in 1946, and the rain-damaged field-cured hay of harvest 4 in 1947. All forage was loaded onto trucks from windrow with a heavy-duty hay loader. Hay was stored loose; silage was pitched off by hand into a stationary ensilage cutter.

[3] Fan operation, electricity, and heat required in addition.

When a field chopper was used (table 4), labor requirements per ton of dry matter preserved for feeding were by far the highest for dehydrated hay, and only slightly higher for wilted silage than for barn-dried hay. There was very little difference in the total equipment-hours required for barn-dried hay, dehydrated hay, and wilted silage.

TABLE 4.—*Labor and equipment-hours required when forage was harvested with a field chopper* [1] [2]

Labor and equipment items	Barn-dried hay [3]	Wilted silage	Dehydrated hay [3]
	Hours	*Hours*	*Hours*
Labor	4. 61	4. 92	8. 35
Tractor [4]	1. 97	2. 37	1. 57
Mower	. 46	. 49	. 45
Rake	. 47	. 48	. 40
Field chopper	. 59	. 64	. 71
Dehydrator			2. 34
Truck [5]	1. 82	1. 66	1. 78
Wagons [6]	1. 80	2. 37	
Tractor [6]	. 75	. 75	
Power unloader	. 60	. 67	
Forage blower	. 60	. 67	

[1] Per ton of dry matter preserved for feeding.

[2] Includes harvests 4 in 1947, 5 in 1948, and 6 in 1949; dehydrated hay, harvests 4 and 5 only. All forage was field chopped and hauled in trucks or by tractor and wagons.

[3] Fan operation, electricity, and heat required in addition.

[4] Does not include tractor used for hauling wagons.

[5] Trucks were used for harvest 4, and for dehydrated hay in harvest 5.

[6] Wagons and tractor were used for hauling barn-dried hay and wilted silage in harvests 5 and 6.

The use of a field chopper made the work of harvesting easier; but because of the small 1- to 2-acre fields and the relatively small loads hauled, field chopping did not reduce the labor or equipment requirements for harvesting and storing. It was comparable for each method of harvesting, however.

The electricity and fuel oil used for barn drying and the gasoline and fuel oil used for dehydration are additional items of expense not required for wilted silage or field-cured hay.

WEATHER EXPOSURE IN SWATH AND WINDROW

The time the forage was exposed to the weather in the swath and windrow for each method of harvesting is shown in figure 1.

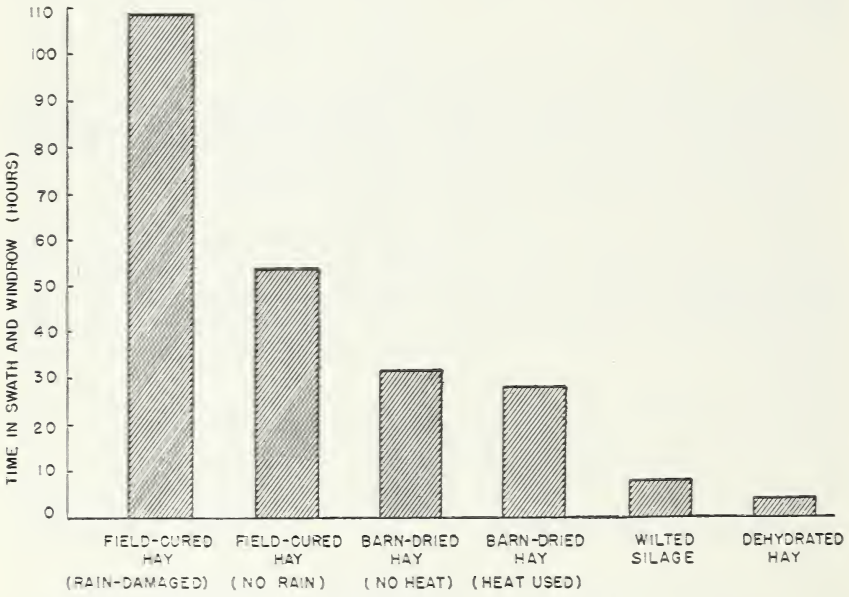

FIGURE 1.—Comparative time the forage was in the swath and windrow when harvested by different methods.

Dehydrated hay was usually dried within 1 to 3 hours after cutting. A small amount cut in late afternoon and a small amount wet by one light shower was dehydrated the next day. Total time in swath and windrow averaged 4.8 hours.

Wilted silage was usually stored within 2 to 5 hours after cutting. Forage cut in late afternoon was left in the windrow overnight. A small amount wet by one light shower was stored the day after cutting. Total time in swath and windrow averaged 8 hours.

Barn-dried hay was usually stored the same day it was cut or the day after cutting. The small amount wet by 1 or 2 light showers was stored the second or third day after cutting. Total time in swath and windrow averaged 29.4 hours.

Field-cured hay stored without rain damage was usually cut one day, raked the next day, and put in storage the second day after cutting.

One light shower delayed storage to the third day after cutting. Two showers on separate days delayed storage to the fourth day after cutting. Three showers on separate days delayed storage to the fifth or sixth day after cutting. Total time in swath and windrow for field-cured hay not damaged by rain averaged 53.6 hours; field-cured hay (light rain damage), 89.0 hours; field-cured hay (heavy rain damage), 131.3 hours; all rain-damaged field-cured hay, 108.6 hours; all field-cured hay, 76.5 hours.

On an average, field-cured hay was exposed to the weather 2.6 times as long as barn-dried hay, 9.5 times as long as wilted silage, and 15.9 times as long as dehydrated hay.

HARVESTING AND STORAGE LOSSES

The percentage of leaves lost during harvesting is shown in figure 2. The percentage of dry matter, protein, and carotene lost in the field

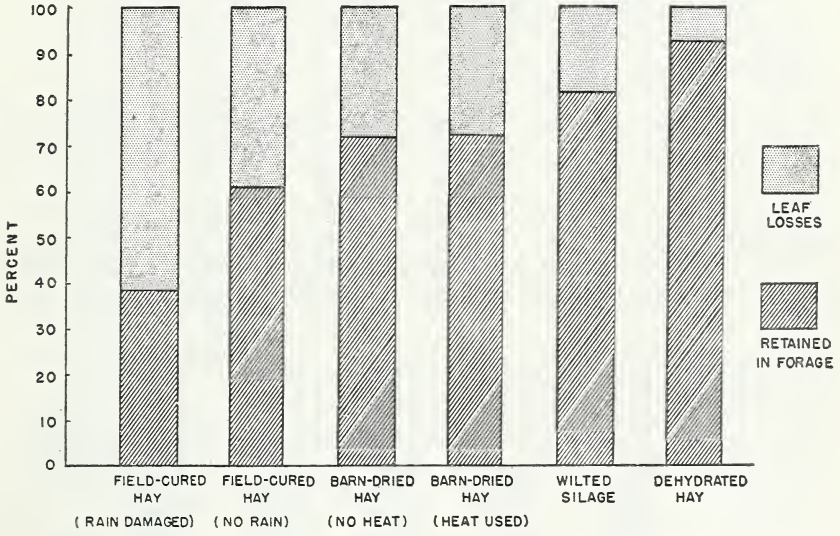

FIGURE 2.—Percentage of alfalfa leaves lost during harvesting, and the percentage retained in the harvested forage, when the crop was harvested by different methods.

and during storage are illustrated in figures 3, 4, and 5, respectively. Storage losses include the losses occurring during barn drying and during dehydration.

Leaf losses ranged from 7.1 percent to 74.5 percent. On an average, leaf losses for field-cured hay were 1.7 times as much as for barn-dried hay, 2.7 times as much as for wilted silage, and 6.7 times as much as for dehydrated hay.

Dry-matter losses (fig. 3) were larger in the field than during storage except for wilted silage. The combined field and storage losses ranged from 9.7 to 39.4 percent. On an average, dry-matter losses for field-cured hay were 1.5 times as much as for barn-dried hay (no heat), 1.6 times as much as for wilted silage, 1.8 times as much as for

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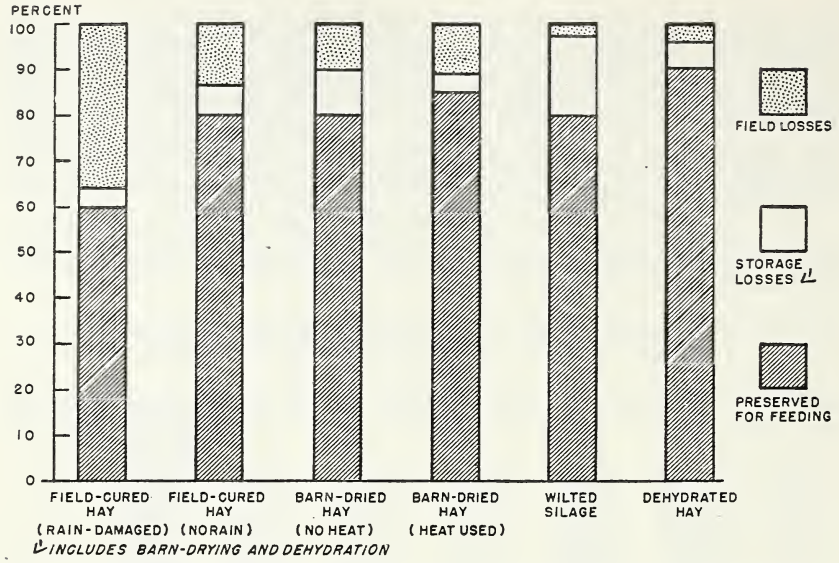

FIGURE 3.—Percentage of dry matter lost in the field and during storage, and the percentage preserved for feeding, when the crop was harvested by different methods.

barn-dried hay (supplemental heat), and 2.8 times as much as for dehydrated hay.

Protein losses (fig. 4) were larger than dry-matter losses. Field losses were larger than storage losses except for dehydrated hay. The

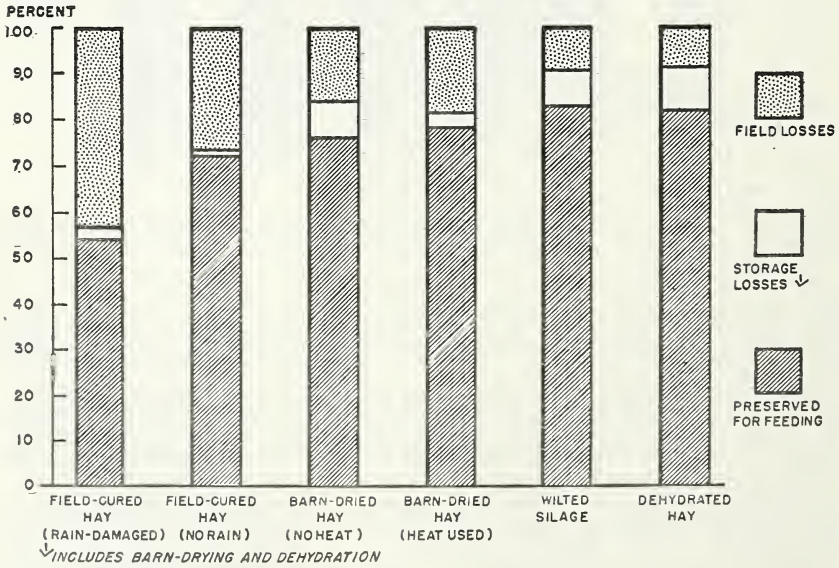

FIGURE 4.—Percentage of the protein lost in the field and during storage, and the percentage preserved for feeding, when the crop was harvested by different methods.

combined field and storage losses ranged from 16.9 to 50.3 percent. On an average, protein losses for field-cured hay were 1.5 times as much as for barn-dried hay (no heat), 1.7 times as much as for barn-dried hay (supplemental heat), 2.0 times as much as for dehydrated hay, and 2.1 times as much as for wilted silage.

Carotene losses (fig. 5) were the largest of all the forage-constituent losses. Field losses were larger than storage losses except for wilted silage and dehydrated hay. The forages having the most carotene when stored lost the most carotene during storage. The combined field and storage losses ranged from 76.5 to 99.4 percent. They were lowest for dehydrated hay. On an average, carotene losses for field-cured hay were 1.05 times as much as for barn-dried hay (no heat), 1.09 times as much as for barn-dried hay (supplemental heat), 1.21 times as much as for wilted silage, and 1.28 times as much as for dehydrated hay.

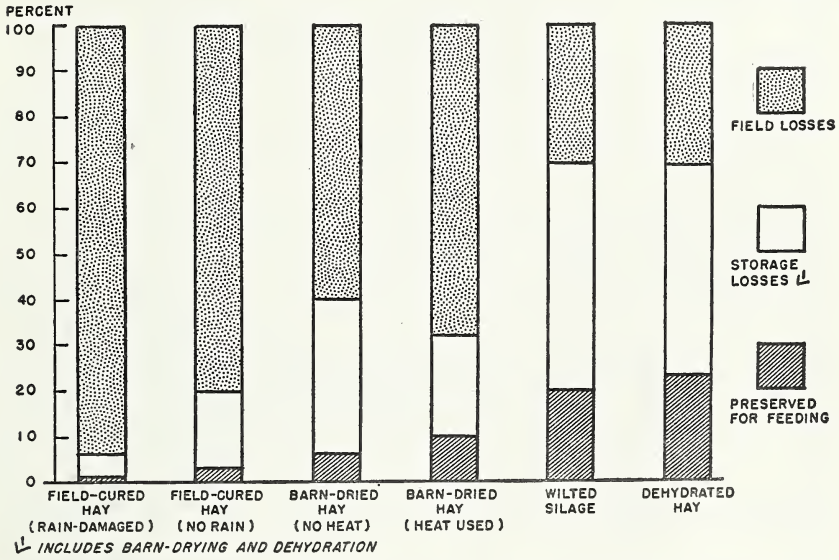

FIGURE 5.—Percentage of the carotene lost in the field and during storage, and the percentage preserved for feeding, when the crop was harvested by different methods.

YIELD, COMPOSITION, AND QUALITY OF THE HARVESTED FORAGES

Table 5 shows the amounts of dry matter preserved for feeding by the different methods of harvesting and the composition and quality of the harvested forages.

Compared with field-cured hay that was not damaged by rain, forage dry-matter preservation for the other harvesting methods averaged: Hay barn dried without heat, 2.5 percent more; wilted silage, 5.3 percent more; hay barn dried with supplemental heat, 7.3 percent more; dehydrated hay, 11.4 percent more. Compared with the average for all rain-damaged field-cured hay, forage dry-matter preservation for the other methods averaged: Hay barn dried without

TABLE 5.—*Yield, composition, and quality of the preserved forages* [1]

Items compared	Field-cured hay			Barn-dried hay		Wilted silage	Dehydrated hay
	Heavy rain	Light rain	No rain	No heat	Heat		
Times compared—number	1	1	3	3	4	6	2
Dry matter preserved for feeding as compared with:							
Standing crop—percent	60. 6	66. 2	79. 0	81. 0	84. 8	83. 2	90. 3
Field-cured hay (rain-damaged) [2]—do	95. 6	104. 2	124. 6	127. 8	133. 8	131. 2	142. 4
Field-cured hay (no rain)—do	76. 8	83. 8	100. 0	102. 5	107. 3	105. 3	111. 4
All field-cured hay [2]—do	83. 7	91. 4	109. 1	111. 9	117. 1	114. 9	124. 7
Composition of dry matter:							
Protein—do	17. 2	18. 3	18. 1	18. 6	18. 5	20. 0	17. 8
Ether extract—do	1. 1	1. 6	1. 9	1. 7	2. 1	3. 4	2. 2
Crude fiber—do	41. 5	28. 7	30. 2	32. 7	30. 5	28. 2	31. 4
Nitrogen-free extract—do	33. 6	45. 3	43. 6	40. 4	41. 9	40. 0	41. 7
Ash—do	6. 6	6. 1	6. 2	7. 0	7. 1	8. 4	6. 9
Carotene—p. p. m. [3]	2. 4	5. 0	12. 0	20. 6	31. 6	62. 0	57. 4
Total digestible nutrients [4]—percent	52. 5	60. 1	59. 1	57. 9	58. 0	60. 4	59. 8
Quality of the forages after harvesting:							
Leafiness—Official U. S. Grade	3	2	1	1	1	1	1
Leafiness—percent	20	38	40	42	40	48	48
Green color—Official U. S. Grade	3	2	2	2	2	2	2
Green color—percent	15	43	50	51	56	56	52

[1] All forage for field-cured hay (heavy rain) was wet by 3 showers on separate days; all forage for field-cured hay (light rain) was wet by 2 showers in 1 day and it was a very high protein, low fiber crop; a small part of the forage of 1 harvest for field-cured hay (no rain) and for dehydrated hay was wet by 1 light shower; a small part of the forage of 1 harvest and half of another harvest for barn-dried hay (no heat) and for wilted silage was wet by 1 light shower; a small part of the forage of 3 harvests for barn-dried hay (heat) was wet by 1 light shower.

[2] Dry-matter yield of all rain-damaged field-cured hay and of all field-cured hay was 63.4 and 72.4 percent, respectively, of the standing crop.

[3] Parts per million of dry matter. For wilted silage, the carotene content was 156, 80, 39, 12, 47, and 38 for harvests 1 to 6, respectively; for dehydrated hay 51 to 63; for barn-dried hay (heat), 15 to 50; for barn-dried hay (no heat), 12 to 28; for field-cured hay (no rain), 6 to 14.

[4] Based on Morrison's estimates of digestion coefficients. (See footnote 2, p. 14.)

heat, 27.8 percent more; wilted silage, 31.2 percent more; hay barn dried with heat, 33.8 percent more; dehydrated hay, 42.4 percent more.

The overall changes in composition and quality from cutting to feeding were smallest for wilted silage and increasingly larger for dehydrated hay; barn-dried hay (supplemental heat); barn-dried hay (no heat); field-cured hay (no rain); field-cured hay (light rain); and field-cured hay (heavy rain).

Wilted silage was leafiest; highest in protein, carotene, and total nutrients; and lowest in crude fiber. Dehydrated hay was about equal to wilted silage, except in protein. Both had sufficient leaf for a U. S. No. 1 grade and the designation "Extra Leafy." Both were a U. S. No. 2 grade for green color.

Barn-dried hay (supplemental heat) had more green color and as much protein as dehydrated hay but was less leafy and lower in total nutrients and carotene than either wilted silage or dehydrated hay. It was a fairly good source of carotene, a U. S. No. 1 grade for leaf, and a U. S. No. 2 grade for green color.

Barn-dried hay (no heat) and field-cured hay (no rain) were both as leafy and as high in protein and total nutrients as barn-dried hay (supplemental heat) but had less green color and carotene. The field-cured hay was lowest in carotene. Both were a U. S. No. 1 grade for leaf and a U. S. No. 2 grade for green color. The barn-dried hay (no heat) was a fair source of carotene.

Field-cured hay (light rain) was much like field-cured hay (no rain) in composition and nutrient content but was less leafy and lower in green color and carotene. It was a U. S. No. 2 grade for both leaf and green color. Its carotene content was too low for long winter-feeding periods.

Field-cured hay (heavy rain) was much the highest in crude fiber and much the lowest in protein, ether extract, nitrogen-free extract, total nutrients, leafiness, green color, and carotene. It was a U. S. No. 3 grade for both leaf and green color. Its carotene content was far too low to meet the animal's need for this nutrient.

VALUE OF THE FORAGES FOR MILK PRODUCTION

The results of five feeding trials to determine the relative feeding value of forages harvested by different methods are summarized in table 6.

The cows were fed the alfalfa forages along with corn silage and low-protein grain. They received all they would eat of the different alfalfa forages during the first 10 days of each 40-day period. The amount fed during the last 30 days was equalized (dry-matter basis) at the level of the least palatable forage.

During the 10-day preliminary periods, wilted silage and dehydrated hay were the most palatable and about equally palatable. The barn-dried hays (supplemental heat and no heat) and field-cured hay (no rain) were all a close second in palatability and all about equally palatable. The badly rain-damaged field-cured hay was unpalatable.

During the 30-day experimental periods, the cows consumed a slight excess of total digestible nutrients over their requirements except when the badly rain-damaged field-cured hay was fed. They consumed considerably more protein than they required at all times.

TABLE 6.—*Results of the feeding trials*[1]

Items compared		Field-cured hay		Barn-dried hay		Wilted silage	Dehydrated hay
		Heavy rain	No rain	No heat	Heat		
Feeding trials	number	1	2	3	3	5	2
Live weight:							
Average per cow	pounds	1,152	1,121	1,154	1,192	1,174	1,168
Gain or loss per cow daily	do	—.19	+.20	—.12	—.12	+.10	+.01
Milk production:[2]							
Initial per cow daily	do	39.5	35.6	35.4	37.9	36.2	37.9
Average per cow daily	do	35.2	34.0	33.7	35.7	34.4	35.7
30-day decline	do	5.5	2.4	2.8	3.7	2.6	2.5
	percent	13.6	6.7	8.1	8.8	7.3	6.4
Feed consumed per cow daily:							
Alfalfa forage	pounds	15.9	19.3	20.8	20.1	48.8	18.5
Corn silage	do	21.2	17.0	17.1	19.3	18.5	19.4
Concentrates	do	10.7	10.2	10.1	10.5	10.2	10.5
Dry matter consumed per cow daily:							
From alfalfa forage	do	14.3	17.7	19.0	18.2	17.9	17.0
From corn silage	do	6.6	4.7	4.8	5.7	5.3	5.5
From concentrates	do	9.3	9.0	8.9	9.2	8.9	9.1
Total	do	30.2	31.4	32.7	33.1	32.1	31.6
Total digestible nutrients:							
Consumed per cow daily	do	19.6	21.2	21.8	22.0	21.7	21.5
Consumed in relation to requirements	percent	98.7	103.5	107.1	107.6	105.1	103.3

[1] Does not include forage from harvest 1 or field-cured hay that had been lightly rained on.
[2] 4-percent fat-corrected milk.

The cows gained a little in live weight on field-cured hay (no rain) and on wilted silage; maintained their live weight on dehydrated hay; and lost a little on the barn-dried hays (supplemental heat and no heat) and the badly rain-damaged field-cured hay.

The different alfalfa forages were all judged to be of about equal value for milk production when fed on an equal dry-matter basis (along with corn silage and grain) except the badly rain-damaged field-cured hay, which was of lower value.

THE QUALITY AND VITAMIN A POTENCY OF THE MILK AND BUTTERFAT

Slight silage flavors were found in the milk of a few of the cows getting field-cured hay and barn-dried hay as well as those getting wilted silage. They were attributed mostly to the corn silage fed along with the alfalfa forages, and probably could have been prevented by feeding the silages after milking rather than before.

Cheddar cheese made from the milk of cows fed wilted silage, barn-dried hay (no heat), and field-cured hay (no rain) was all excellent in quality and U. S. No. 1 in grade.

The color of milk and fat and the vitamin A potency of the butterfat were closely related to the daily intake of carotene (table 7). Carotene intake and vitamin A potency were highest on high-carotene wilted silage, followed in order by dehydrated hay, medium-carotene wilted silage, barn-dried hay (supplemental heat), low-carotene wilted silage, barn-dried hay (no heat), field-cured hay (no rain), and field-cured hay (rain-damaged).

TABLE 7.—*Relationship between carotene intake per cow daily and the vitamin A potency of butterfat* [1]

Alfalfa forage	Carotene content as fed	Carotene intake per cow daily [2]	Vitamin A potency of the butterfat [3]
	Parts per million of dry matter	*Micrograms*	*International units per pound*
Wilted silage	156	890, 000	18, 385
Dehydrated hay	63	637, 590	11, 480
Wilted silage	80	650, 030	11, 345
Dehydrated hay	51	439, 580	10, 210
Barn-dried hay (heat)	41	391, 160	10, 330
Wilted silage	47	343, 400	9, 440
Barn-dried hay (no heat)	22	217, 940	8, 635
Field-cured hay (no rain)	12	141, 060	8, 140
Field-cured hay (rain-damaged)	2	76, 305	7, 800

[1] Average for all 3 periods of a feeding test in each case.

[2] Includes carotene in the corn silage consumed. This varied greatly between feeding tests.

[3] Vitamin A was determined at the end of each feeding period. The dates ranged from Dec. 20 to 30, Feb. 1 to 10, and Mar. 10 to 20, respectively.

VALUE OF THE FORAGES FOR GROWING DAIRY CALVES

To determine their antirachitic effect, each of the forages from harvest 2 (field-cured hay, barn-dried hay, and wilted silage) was fed to growing dairy calves over a 6-month period. The calves were about 5 months of age at the start of the experimental feeding period. They had been weaned previously from milk and had been fed a low vitamin D ration until they showed signs of rickets.

Each forage was fed as the sole roughage to 2 calves at each of 3 levels—0.5, 1.0, and 1.5 pounds of dry matter daily per 100 pounds of live weight. The calves each received 4 pounds of skim milk daily and enough grain in addition for normal growth according to the Morrison standard.[2] The calves were kept in a darkened barn during the day and were turned out in a dry lot at night for exercise.

The vitamin D content of the forages per gram of air-dry material was as follows: Field-cured hay (no rain), 0.97 international unit; barn-dried hay (no heat), 0.49 international unit; and wilted silage, 0.56 international unit.

For all 3 forages, gains in live weight were normal and about equal at all 3 levels of feeding. All 3 forages contained enough vitamin D to protect calves from rickets when fed at levels of 1.0 and 1.5 pounds of dry matter daily per 100 pounds of live weight.

The calves fed wilted silage consumed the highest quantities of dry matter. They were sleek in appearance and did as well throughout the experiments as the calves fed hay. However, experiments now in progress indicate that hay is a better feed than silage for calves up to 90 days of age, and for older calves that get little or no grain.

PRACTICAL APPLICATION OF THE RESULTS OF THESE EXPERIMENTS

Experiments conducted at Beltsville, Md., over a 5-year period have shown that in climates where rain occurs frequently during hay harvest it will be to the farmer's advantage to harvest his hay crop as silage or as barn-dried hay rather than as field-cured hay. Dehydration may be advisable under special conditions. In these experiments, more nutrients were preserved by making silage or barn drying the hay crop than by field curing, even when weather conditions were favorable for field curing.

Making silage from the hay crop has many advantages. It is a good way to handle heavy, weedy, first-cutting crops that are ready to harvest during damp, cool weather and are hard to cure as hay. If the first crop is cut at an early stage of maturity, it will be easier to handle; the silage will have a high content of carotene, protein, and digestible nutrients; and the yield from the second cutting will be larger.

Although types of silos were not studied in these experiments, it is known that silage may be stored chopped in tower silos and either

[2] Morrison, F. B. feeds and feeding. Ed. 21, unabridged. 1207 pp., illus. Ithaca, N. Y. 1949.

chopped or long in trenches or stacks. With proper handling, losses will be smallest in tower silos. Losses will be a little larger in lined trench silos (on well drained ground), and these silos provide cheap storage space and are easy to fill and empty. Stack silage can be made to advantage only when there are surplus yields of high-moisture crops that cannot be stored as silage otherwise, as the storage losses will be high.

Immature high-moisture crops make better quality silage and the cows will eat larger quantities (dry-matter basis) if the moisture content of the forage is reduced slightly by wilting in the field or by adding dry chopped hay or grain to the chopped forage as it is stored in the silo. The moisture content of the forage should not be reduced below 60 to 65 percent in the bottom of a tower silo or 65 to 70 percent in the bottom of a trench silo. Heavy unwilted crop should be used on top to provide the weight and pressure needed for thorough compaction and a good top seal. Stack silage should be made throughout with unwilted crop containing 75 to 85 percent of moisture.

The dehydrated forage made in these experiments with a portable dehydrator was high-quality forage, and harvesting losses by this method were lower than by any other method. However, the forage could not be harvested as rapidly as desired and the labor and equipment requirements per ton of dry matter preserved were much higher than by any other method. Immediately after dehydration, forage has a very high carotene content, which is one of its principal marketing assets. To maintain the carotene content at or near this high level until the forage is sold or fed, it is necessary to cool the forage right after dehydration and to keep it in cold storage. It appears that dehydration is better adapted for large commercial installations and round-the-clock operations where crops and markets are large enough to make full use of labor-saving equipment.

Dehydration with a small portable dehydrator required from 3 to 6 gallons of gasoline and from 25 to 60 gallons of fuel oil for each ton of dry matter preserved. The investment for a dehydrator of this type will be from $8,000 to $10,000, exclusive of field equipment and storage facilities. Commercial installations of single stationary units having a capacity of a ton or more of dry chopped hay or meal per hour, together with all the field equipment and dehydrating and storage facilities for round-the-clock operation, cost from $50,000 to $150,000 each.

As compared with field-curing, making the hay crop into silage offers a means of more efficient preservation of the nutrients in the crop and, when fed to dairy cattle, results in milk that has a higher nutritive value because of its higher carotene and vitamin A content.

Barn drying a hay crop with forced air is a valuable supplement to field curing or silage making. Supplemental heat should be provided in humid climates if a large amount of hay is to be dried. The hay can be dried long, chopped, or in bales in a haymow, stack, or pole shed. To keep drying losses low and to make a good grade of hay, the forage should be barn dried down to 12 to 15 percent of moisture in 4 days or less.

Unless there is plenty of supplemental heat available, the hay should be partly field cured—down to 40 to 45 percent of moisture when stored long, 35 to 40 percent when stored chopped, and 25 to 35 per-

cent when stored baled. The drier fan should deliver at least 25 cubic feet of air per minute per square foot of floor area. Heating equipment should be capable of producing a temperature rise of 20° F. or more.

Care should be taken not to store the hay too deep for drying within a reasonable time and not to compact loose or chopped hay in spots while it is being stored. Care should be taken also to make the pile sufficiently wide so that too much air will not escape at the sides. Baled hay should be stored on edge with the bales placed as tightly together as possible. The use of a large canvas tarpaulin cover over the baled hay will result in better drying of the top and outside bales.

The investment required for a mow hay drier having 1,000 square feet of storage space will be from $800 to $1,000 if unheated air is used and from $1,800 to $3,000 if heating equipment is installed. From 35 to 90 kilowatt-hours of electricity are required per ton of dry matter preserved when no heat is used. The use of supplemental heat requires from 7 to 30 gallons of fuel oil per ton of dry matter preserved but reduces drying time and electricity requirements by about 60 percent.

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